On a Photograph of the Solar Spectrum, showing Dark Lines of Oxygen. By Professor J. C. Draper.

(Communicated by W. H. M. Christie, Esq.)

I send by mail, with this letter, a photograph of a solar spectrum of the third order, in the vicinity of G. It is an original photograph of the diffraction grating spectrum itself. It has not been enlarged nor manipulated in any way whatever. It was taken on October 1, at the City College, and though the sky was not perfect, it is a good picture. If you think it good enough, I should be very much obliged if you would present it at a Meeting of the Royal Astronomical Society, for the inspection of members who take an interest in these matters.

The apparatus was essentially that described in the *American Journal of Science* for October 1868, page 256. It consisted of Heliostat with silvered glass mirrors, slit, silvered glass concave mirror, silvered glass Rutherfurd grating of over 17,000 lines to the inch, and a camera box. The light passed from the grating to the collodion plate, with nothing intervening except the glass bearing the scale, as described below. In the case of that part of the spectrum which does not bear the scale, nothing whatever except air intervened between the grating and the collodion on the plate.

The slit aperture with which the picture was taken was exceedingly fine, probably $(\frac{1}{3000})$ one three thousandth of an inch in width, and possibly less. Even with exposures of six and seven minutes, and a very sensitive collodion, the fineness of the slit has rendered it necessary to force the development of the image, hence come the minute spots on the film.

As the red of the second order overlaps this portion of the third order, one of your half-prisms, made for me in New York, was used for the separation of these orders in focussing. It was placed in the aperture of the focussing glass, and almost touched the clear glass plate of the camera, which occupied the position ordinarily held by ground glass.

The picture may be studied either as a positive or as a negative. In the first case, it is to be laid on a black background of velvet or cloth, and viewed by reflected light, when the dark lines represent the absorption lines and the white lines the bright or coloured spaces in the solar spectrum. In the second case it is to be held between the eye and the light of a white cloud (at night a light, with a ground-glass shade), and viewed by transmitted light. Thus examined with a suitable magnifying power, the clear spaces represent the dark lines of the spectrum, and the dark lines of photographic action, the bright parts of the spectrum. This must be borne in mind when making examinations in connection with the descriptions given hereafter.

The cross lines near the centre of the plate indicate the position of the line of no deviation for the apparatus described. The

capital letter G is written on the back of the plate bearing the collodion film. It is over the line G of the solar spectrum, and a little to the left of the line of no deviation. On the right of the line of no deviation, and beginning at the cross lines, five bands appear, the third and fourth containing what I believe to be dark lines of oxygen. The collodion film is protected by a second plate of glass, as the picture is not varnished. The two plates of glass are separated by a mat, made of blotting paper. The glass on which the collodion film rests, being ordinary photographic glass, is not suited for measurement of the spectrum lines by projection.

To examine the picture, hold it in such a position that the letter G reads properly. Then, using a moderate magnifying power ($2\frac{1}{2}$ to 3 inches focus), as before described, and viewing by transmitted light, a scale bearing divisions and figures will be seen above the line which runs the whole length of the photograph, and which divides it into two portions.

The manner in which this scale was introduced was as follows: On a slip of the flattest glass I could find, a scale of 200 half-millimetres was ruled. This was fitted in the plate-holder of the camera, in front of and close to the collodion film, with the ruled side of the plate looking toward the collodion. It was carefully adjusted to intercept one-half of the spectrum. Its shadow was thus cast with this half of the spectrum upon the collodion film, and so the scale was printed by the spectrum itself. The line which traverses the whole length of the spectrum is the edge of the glass upon which the scale is ruled. The scale I have introduced here merely as a means of indicating positions. Its real purpose is to verify readings of wave-lengths made by the projection process I have heretofore described.

The necessity of avoiding the intervention of anything between the grating and the collodion film is shown by the injury to definition and obscurity produced in the upper half of the spectrum by the glass on which the scale is ruled. In the case in question the obscurity is increased by vapours which arise from the collodion and condense on the glass scale.

To study the picture intelligently, take one of Dr. Rutherfurd's admirable photographs of this part of the spectrum; a series of five bands will be found on the less refrangible side of G. In the photograph I have used, their positions, as read by the scale attached, are as follows:—

1st	4312·60	to	4314·15	These readings may vary slightly in different photographs, owing to difference in stretching of the paper used for the photographs and the scale; but they serve to indicate the bands in question.
2nd	4314·60	,,	4316·10	
3rd	4316·20	,,	4317·95	
4th	4318·15	,,	4320·00	
5th	4320·25	,,	4322·15	

Take H. Draper's photograph, published in *Nature* for August 30, 1877, the five bands are easily identified, and the oxygen

lines in the spectrum below correspond to the third and fourth of these bands. In his article discussing the oxygen lines, he gives their wave-lengths as 4317 and 4319. In support of the opinion, that it is in this part of the spectrum that oxygen lines should be found if any exist, I refer to the diagram given in the *Observatory* for June 1879, page 47. The wave-length values of these oxygen lines, as given by the authorities there presented, are:—

Ångstrom.	J. C. Draper.	Plucker.	H. Draper.	Huggins.
4316·20 4316·95	4316·50	4317·	4317·	4318·
4318·85 4319·45	4319·75	4320·	4319·	

All agree in placing them within the limits of the third and fourth bands of Rutherfurd's photograph.

Take my photograph of the 3rd order, October 1, 1879. The five bands are easily identified, and present the following scale readings:—

1st	97·95	to	100·10
2nd	100·45	,,	102·35
3rd	102·75	,,	104·70
4th	105·40	,,	107·25
5th	107·70	,,	110·10

Remembering that the picture is now studied as a negative, and that the clear spaces are the dark lines of the solar spectrum, it will be seen that each of these five bands contains dark lines. In some instances also, and notably in the case of the line separating the 3rd and 4th bands, the separating line is double. An experience gained by the study of more than 200 photographs of this region leads me to think that many of the lines given in the following Table of the lines contained in these bands are really double:—

	Scale Number.
Lines in 1st band	98·65 99·25 100·00
Separating line	100·30
Lines in 2nd band	100·85 101·65
Separating line	102·60
Lines in 3rd band	103·20 103·55 104·20

	Scale Number.
Separating lines	104·85 105·30
Lines in 4th band	105·80 106·20 106·60 107·00
Separating line	107·50
Lines in 5th band	108·10 108·60 109·70
Separating line	110·20

As regards the photographic intensity of these bands when compared with that of the lines between 70 and 80 of the scale, no one can have any doubt of its superiority in the latter case. To a careless examiner it may appear stronger in the first, but this is a deception caused by the great width of the bands.

In answer to objections that may be advanced against these lines in the 3rd and 4th bands as oxygen lines, on account of their lack of intensity, I submit the appearances offered by the picture. I would also suggest that, since both oxygen and nitrogen are really the only non-metallic gaseous elements that approach a permanently gaseous state, we should be prepared from this fact alone to expect them to produce only faint absorption lines in the solar spectrum.

It also seems to me that the picture really gives us the true spectrum of oxygen, for this region, under the conditions existing in the solar envelopes, viz. that it is a spectrum of six faint lines in two bundles, corresponding to those in the 3rd and 4th bands of the picture.

If we admit that the electric oxygen bands corresponding to this position are really composed of lines, and that the attenuated condition of gaseous oxygen in the Sun explains the faintness of oxygen absorption lines, we have no difficulty in accepting the opinion that oxygen is present in the solar envelopes, and that it acts there in the same manner as any other elementary body, and produces its proper dark absorption lines in the solar spectrum.

As regards the appearance of the picture from a photographic point of view, I would say that, if the slit is opened sufficiently, there is no difficulty in obtaining a more pleasing picture with a brief exposure. But, on opening the slit, purity of spectrum disappears, and as the slit is widened the lines fade away, until at last nothing remains but the five unlined bands, as is shown in H. Draper's photograph in *Nature* of August 30, 1877.

That there is nothing peculiar about this photograph of the 3rd order is shown by the fact, that in photographs of the 1st order the resolution of these five bands is foreshadowed, in those of the 2nd order it is partly accomplished, and in the 3rd order the dissection is completed, as you see.

New York, 1879, *Oct.* 9.

On the Working of the Speculum for Mr. Common's 37-inch Silver-on-glass Reflector. By Mr. G. Calver.

The Speculum recently finished for the 37-inch Reflector gave me an opportunity of coping with the difficulties to be encountered in making a large speculum of this kind. I have found some of these difficulties to be less than I anticipated; and I believe considerably larger instruments might be undertaken with a reasonable prospect of success.